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A CAS Approach to Equipment Campaign Simulation and its Application

Chen Yuefeng[a,b], Xiao Shunwang[a], Song Huting[a], Liu Feng[a,a*]

[a] *63963 units, the 3th yard of fengtai district in huaishuling, Beijing 100072,China*
[b] *66393 units, the seven-one middle road,Baoding 071051,China*

Abstract

In this research, CAS (complex adaptive system) theory was introduced and its technology architecture was constructed including of computational model, simulation platform and so on. Furthermore a new approach was established to equipment campaign simulating on this method. Two application cases were realized based this theory and technology architecture, including battle damage simulating model and equipments counterworking model.

Nomenclature

A	radius of
B	position of
C	further nomenclature continues down the page inside the text box

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* Corresponding author. Tel.: +08601-13718892560; fax: +08601-010-66862384.
E-mail address: yuefengch@163.com.

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1. Introduction

Equipment campaign system refers to the activities focus on preparing and implementing war. It must be concerned about complex intelligent behaviors including of constructing of military force, the preparing of campaign and the research of military science. Equipment campaign system may be defined a living group that is consisted of many elements and special purpose. Equipment campaign system is war-likely and gathering locally, such as campaign system in different level and scale, support system of rescuing and repairing damaged equipment in battlefield. These systems may be consisted of many homogeneity and heterogeneity interactional elements. There are many typical features such as concurrency spatially, collectivist couplings，random factors, human being and so on.. Based on way classifying system by Qian Xuesen, these systems was similar to economic system and social system, namely special complex gigantic system.

Complexity concept come out at second half of 20th on science and engineer technology fields. From the view of complexity science, the complexity of military system root on its objective attribute such as following aspects: (1) Multilayer Multi-layer is one feature of many military system, and a steady-going order structure. The typical example is that corps and which of services almost adopt the construct of army, troops, camp, company, and platoon. Multilayer in support system embody as operational level, intermediate level and depot. This character lead to the emergency behavior happens through lower levels. (2) Opening Military system is opening system, the exchange of substance, energy and information take place interior and exterior. (3) Nonlinear Military system is made up of many sub-system, cooperation or confined take place among of them, so nonlinear effect is produced . (4) Dynamic Military system is on developing status and structure, function, behavior is evolving toward high modality by self-adaptive and self-organize. (5) Uncertainty A great deal of random, fuzzy factor act on the system. System developments become beyond prediction; and so on.

Obviously complexity leads to constructing whole model hardly possible. So we try to apply CAS theory to analysis these systems and explore research scheme.

2. Exploring Modeling Approach form ABM

Nowadays, ABM became a prevalent role in complex system. Form ABM modeling case, a common modeling framework may be found， which meet the characteristic of equipment campaign modeling.

2.1. ABM Case and Feature

From current ABM case based on complex adaptive system CAS (complex adaptive system) theory, two features may be found. First the entity defined as agent is not fixed on the alive but all kinds being schemed in schedule. Second space was imported into model, the interaction of agent and space became the center of system. For example, in reference [1] the equipment and material were treated as agent, which behaviors are simple such as fault, halt and maintenance. In reference [2,3] ISAAC model combine agent with space model of cellular automaton(CA), CA was used to defined geography environment and control agent position. In reference [4] SSS（Swarm Sugar Scape）model use a space model of three layer cellular automaton. Sean Luke in George Mason College develops a Viom3d model on MASON platform, which simulate worm colliding with obstacle in a 3D continuous space in reference [5]. Therefore we may try to construct an Agents/Space approach, in which agent may be all kinds of entity and space model was import on system researched.

2.2. An Agents/Space Approach

Obviously Agents/Space architecture may provide a universality and intuitionist approach, and more abundant modeling capability than ABM. This approach decomposed system as agent, object, environment and rule. Agent represents that entity taking complex behavior, and object represents that fixed entity. The core of agents/space lies in Agent Behavior Model describing interaction of agent and environment (from production system to complex arithmetic), and Space Model adopted (cellular automation, continuous space and so on) (See Fig.1).

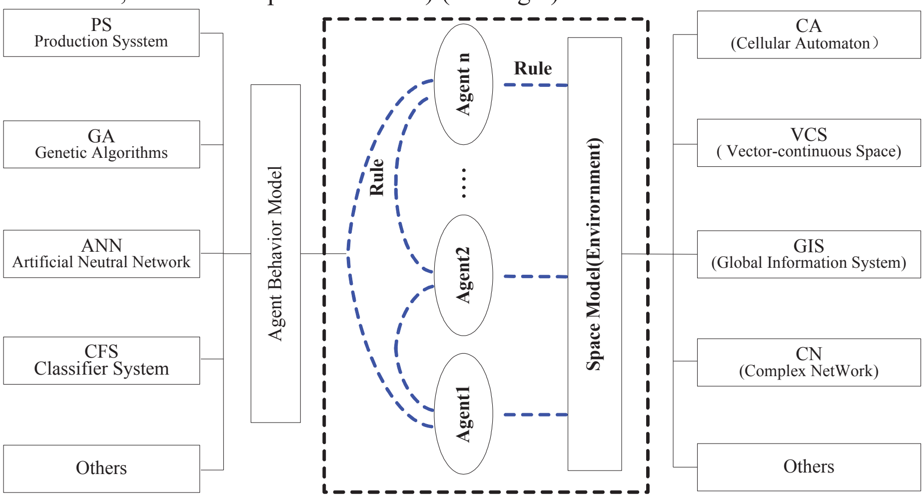

Fig. 1.An Agents/space architecture of modeling and simulating

The theory base of this architecture is complex adaptive system (CAS) by J.Holland who is founder of genetics arithmetic, which emphasized to decompose system as many agents and combine them into a multi-agent system by environment, and the complex interacting behavior of inner system was simulated dynamically, and the inner states of agent or environment was gathered as system law.

2.3. Key Technology

The key technology of Agents/Space architecture is computational model (CM), which embody a modular modeling idea, which is integration of mathematics model, behavior model and correlative algorithm, which may be quantitative or qualitative or from qualitative to quantitative, which is formally a code block in simulating program as function, class, interface or software.

Computational model may be classified into Agent Behavior Model and Space Model on agents/space architecture.

- Agent Behavior Model: it describes the basic behavior of entity, which apperceives environment and adopts corresponding action. In this architecture some computational model may be adopted according to problem feature such as production system, neural network, classifier system and genetic arithmetic.
- Space Model: it maps system space and control element location. Space model may include cellular automation, continuous space, geography information system (GIS) and complex network. GIS may reflect adequate geography information feature. Complex network may simulate society network, Internet and command control network.

To develop target system on existing platform may gain in avoiding foundation work, enhancing develop progress and reusing model. Some ABM platform may sustain agents/space architecture such as

Swarm, Mason, Repast and Netlogo in some extent [6,7,8]. To choose platform lie in tradeoff in developing convenience and modeling capability.

3. Equipment Battle Damage Model

To construct equipment battle damage model, equipment target, hull and inner component may be described including its structure, geometry and physics attribute. Damage effect may be fixed on debris behind armor which is main damage factor to inner component.

3.1. Model Design

To modeling equipment battle damage on Agents/Space approach, anti-tank projectile and its damage effect behind armor may be modeled by agent technology, equipment may be treated as model environment, to damage relation may be modeled by interacting of agent and space.

- **Anti-tank projectile and its effect**
- Anti-tank projectile and its damage effect behind armor were modeled by agent, two kinds of agent should be developed including of Piercing_Agent to projectile and Debris_Agent to single debris of BAD.
- a)Piercing_Agent's behavior includes aiming equipment and controlling the direction and energy scatter of BAD. Its main behavior is following:
- *Choosing an aimed board:* Because of war complexity this relation takes on uncertainty feature, which distributing relies on campaign fashion. Here an experience formula was adopted for general campaign as following [9]:

$$\rho\ (\theta_1 \sim \theta_2) = 0.1\left[\Delta\theta/360 + 0.596\left(\cos\theta_1 + \cos\theta_2\right) + 1.157\right] \qquad (1)$$

- ρ presents the aimed probability of equipment in polar coordinates, the center of equipment is polar origin o , direction of going forward is as polar axis, counter-clockwise angle with polar axis is as θ (+).
- *Damage effect behind armor:* After piercing armor a damaging debris field was shaped as ellipse taper. There is no an admitted way for BAD model, experiential parameters was often adopted.
- b)Debris_Agent represents single debris in BAD, which behaviour includes moving in equipment, damaging inner component and destroying its self.
- *Moving track:* based on line equation the arithmetic of Debris_Agent moving track is as following:

$$\begin{aligned} x &= x_0 + t \cdot \cos\{[360° - (\theta_s \pm \delta)] - (\theta_c \pm \delta) \pm \phi\} \\ y &= y_0 + t \cdot \cos[(\theta_s \pm \delta) \pm \phi] \\ z &= z_0 + t \cdot \cos\{[90° - (\theta_c \pm \delta)] + \theta_c + 360° \times r_7\} \end{aligned} \qquad (3)$$

- In the equation (x0, y0, z0) is coordinate of aimed origin, θs is horizontal incidence angel to vertical axis, θc is vertical incidence angel to horizontal plane, δ is a turning angel to normal line, φ is crossing angel of this track and center line of BAD, r7 is random of even distributation.
- On this track arithmetic a simulating step was given, Debris_Agent may move in equipment. Inspect arithmetic in Mason platform may be used to detect front component.
- *Distinguish damaged:* P_{hk} represents damaged probability of component hit by debris. While P_{hk} equal 1, the target was damaged. While P_{hk} equal 0, the target was not damaged.

$$\begin{cases} p_{hk} = 1 \text{ while } e_s \geq H_s \\ p_{hk} = 0 \text{ while } e_s < H_s \end{cases} \qquad (4)$$

- In this equation e_s is kinetic energy of debris, *Hs* is equivalent thickness of this section.
- **Equipment environment**
- To build equipment model, board and inner component were defined in 3D continuous space computational model of Mason platform, which may control position of the piercing projectile and its effect at the same time.
- a)Hull of equipment may be partitioned as boards, every board was created through inheriting Shape3D class from Java 3D, meanwhile board class should mention normal vector, boundary angle and thickness of this board. The attribute of board class may be defined as following:

  BoardAttributes（Point[4], AimedBoundaryAngle, ThicknessofBoard, NormalAngle）.
- In this definition Point[4] represents four peak of board, AimedBoundaryAngle is boundary angel, ThicknessofBoard is thickness of this board, NormalAngle is normal vector of this board.
- b)Inner component was represented by a group of cell, and every cell takes on regular geometry figure. Obviously these components bear 3D space structure and discrete attribute and state value. To build this model, component was partitioned a group of cell, then vulnerability threshold and damage grade of cell were defined.

  Attributes of every cell may be defined as following:

  CellAttributes（Position[3],VulnerabilityThreshold, DamagedGrade）.
- In this definition Position[3] represent space position of cell, VulnerabilityThreshold represents vulnerability threshold of this part, DamagedGrade represents damage grade of component damaged.

As to component composed of a group of cell, attributes value of cell may be defined on its position in component.

3.2. Model Implementing

Battle damage model of equipment was consisted of two sections on Mason architecture. DPModel is basic model presenting interaction of projectile and equipment, which is self-inclusive class and inherits SimState superclass. Besides there is a visualizing module DPModelWithUI and a top control module BatchDPModel for batch simulation.

In DPModel starting simulation, stepping schedule and shutting program may be realized by Mason panel. EquipmentEnvironment and PeriecingAgent are two basic objects of DPModel. PeriecingAgent' behaviors include piercing armor and controlling the debris field behind armor. DebrisAgent is a new object after hull pierced, which behavior include moving in equipment and damaging inner component. EquipmentEnvironment is a collection of board and inner component, every component was consisted of a group of cell, which attribution rest with its position.

DPModelWithUI is visualizing class inheriting GUIState, which bond DPModel to portrayals and display to realize visualization. Three dimension scenes may be visualized on Mason of Java3D. A series of standard portrayals was provided on Mason, which may realize BAD visualization. As to equipment with boards and inner components, visualization was realized through inheriting SimplePortral3D superclass. Simulating scene of this model sees Fig.2. In order to inspect inner component damage, hull of equipment was treated as line frame. Left figure show BAD while the foreside was aimed. Right figure shows the aimed cell turn its colors. Simulating scene may be drag and rotate to inspect on different view.

DPBatchModel was used to large-scale batch simulating that damage probability distributation was acquired. Only the equipment parameters and the experiement value of BAD were input model as data file, it may start DPModel to simulate battle damage. As to simulating result, Mason don't provide special statistic class, in this model JFreeChart was used. Fig.3 provides change curve of inner component so that the trend of damage may be observed to control simulation, namely simulation was closed when the trend near some value.

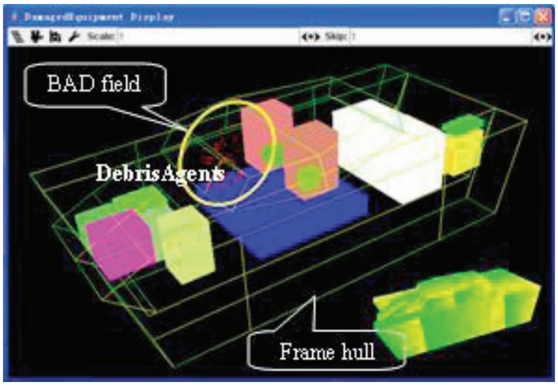

Fig. 2.An Agents/space architecture of modeling and simulating

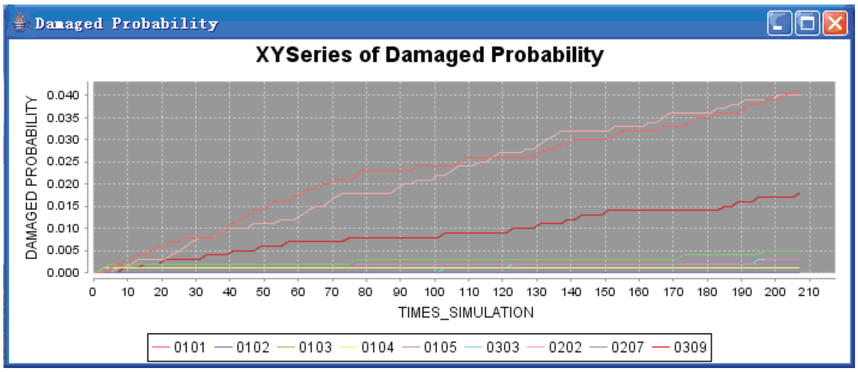

Fig.3 XYSerices of component damaged probability with simulating time

4. Multi-Equipment Counterwork Model

The equipments counterwork model focuses on simulating antagonizing and striking of two sides in hypothetic background. In our research the model was attached micro detail on agent/Space scheme, and emerging whole mechanism of system through interaction of agents, agent and environment.

4.1. Designing Model

Under this scheme we take equipment as agent, describe the interactive rules among equipment agents, agent and environment on assumed battle situation. The main characters of the battle damage model on agent/CA scheme are as following:

- *1) Agent and its rule*. In this model equipments were treated as agent, which has damaged attribute and can be changed in interacting process between agent and environment. Rule embodies as the interaction among agents, agent and environment. The main rules of model include moving rules, attacking rules and damaged rules. Production system was adopted on operation theory in this model.

- *2) Designing of Environment.* To each agent, the environment refers to the whole except agent itself, including battlefield landform, enemy threat, organization of equipment group and tactics etc. In order to show the battlefield environment objectively, we adopt multi-layer cellular automata to describe the landform layer, firepower deployment layer, arms and equipment layer and strategic target layer.

4.2. Implementing Model

As the general RePast program, the battle damage model includes “SimModelImpl” compenents. It is assembling workshop of equipment battle mechanism model, which includes a group of agents, environment, and activity schedule of agent. Namely the model component including equipment agents of two sides and multi-layer environment, and the inaction sequence of events implemented by schedule was assembled. The sequence of agent’s activity is as follows: equipment agent detects the geographical environment parameters around it, accounts the number of equipment agent alive, then determines its status either damage or survival according to the assumed enemy threat rules. Finally all equipment agents will construct a new pattern of existing state.

BuildDisplay（） is a key approach of SimModelImpl class, which function lie in observering the simulation result through diagram object. In this model the widget show the survival equipment at each moment. Figure.3 shows the movement of 60 equipment agents on 100×100 cellular automaton. Each agent was marked into seven sectors to describe its damaged state. On the figure landform can be distinguished clearly, blue curve stands for river, grey curve symbolizes road, black marks mean barrier and the rest green area is common landform. Equipments of two sides are deployed in such a landform, the red bits represent equipment of Red Side and the brown ones represent equipment of Blue Side respectively. Figure.3 indicates the adjustable parameters in the model, which are the input of the model. The number of equipment agent observed is determined by the parameter of numtanks in SimModelImpl.

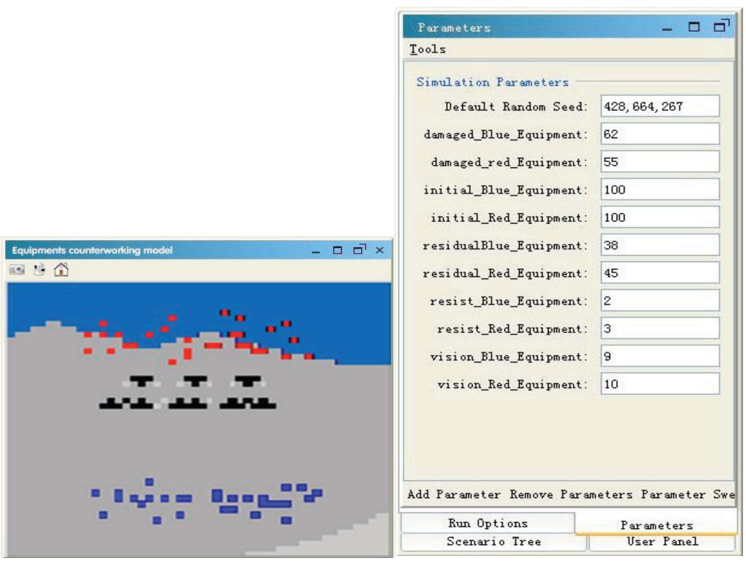

Fig.4 simulating scene and control pannel

5. Conclusions

Complexity science provides effective theory foundation on researching equipment campaign complex system. In our research work spatial model was combined into multi-agent technology, and the typical complexity of equipment campaign system can be effectively resolved. Meanwhile the idea of integrating arithmetic and model in constructing model was realized through agent behavior model and spatial model. Two typical equipment campaign simulating model of equipment battle damage and equipments counterworking model were realized. Own to validity and advantage of this scheme it may be applied in military system on analogous characteristics.

6. Copyright

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